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CAVE CONSERVATION: SPECIAL PROBLEMS OF BATS

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ABSTRACT

Ignorance as to the real status of populations of almost all bat species is a major problem for their conservation. This ignorance is reflected in the IUCN "red list" of threatened species, which is both minimalist and biased. The recent proposition that we should construct "green lists" of species known to be secure, rather than red lists, is extended to bats. Available information regarding the status of the five species of North American bats listed as endangered is reviewed, and these species are used to illustrate major problems encountered by bat populations. All of these species rely on cave roosts. Their habit of roosting in large aggregations during hibernation and/or reproduction make these and other cave dwelling bats particularly vulnerable to disturbances which can reduce populations. Types of disturbances and their likely effects are discussed. The long-life spans and low reproductive rates of bats mandate that they will recover slowly following population reductions. Habitat alteration and destruction outside of roosts and poisoning from pesticides also have impacted negatively on bat populations; however, roost site disturbance and habitat destruction have probably had much greater negative effects than has pesticide poisoning. Because disturbance within their cave roosts is a major problem in bat conservation, constructing lists of "green caves" (those which can be visited) and "red caves" (those which must be avoided) is encouraged. Criteria for constructing these lists of caves are discussed.

RED BOOKS, GREEN LISTS, AND A LACK OF INFORMATION

Each year the International Union for the Conservation of Nature (IUCN) updates the Red Data Book which lists plant and animal species known to be endangered, vulnerable, or rare. The 1988 Red Data Book places 33 bat species in these categories. As there are approximately 900 species of bats in the world (nearly one-fourth of all mammal species), this "red list" of threatened species includes less than 4% of the world's bats. This disproportionately small number should lead anyone with even remote awareness of the worldwide extinction crisis to question whether this list reflects reality with regard to bat species that are threatened. In reality, the red list does not come close to giving an accurate picture of the problem.

First, consider that the red list has a substantial geographical bias toward North American species. The standard reference on North America bats (Barbour and Davis 1969) lists 39 species of bats in North America, north of Mexico. These 39 species comprise about 5% of the worldwide bat species diversity. However, of the 33 threatened bat species on the IUCN list, 5 are native to North America. So, a fauna comprising 5% of total bat species diversity, accounts for 15% of the species considered as threatened. I argue that this bias does not reflect reality with regard to species endangerment. Rather, this bias reflects our ignorance regarding the status of most bat populations. We simply know the status of bats in North America better than for most other parts of the world. I also argue that our degree of ignorance is even more frightening when you recognize that we are not even certain how accurate the IUCN red list is for bat species in North America. This is so because for most bat species in North America, much less for those elsewhere (particularly in the tropics), we simply do not have the information to determine whether overall population sizes are stable, decreasing, or if they are decreasing, at what rates? So our ignorance on the status of bats is extreme. Given this ignorance, the IUCN red list gives a highly inaccurate and minimal assessment of our current extinction crisis.

Recognizing this, prominent conservation biologists recently have suggested that the construction of red lists has been a major tactical error by those who wish to preserve the world's biota (Imboden 1987; Diamond 1988). Red lists are thought to be a tactical error because the existence of such a list may lead to the assumption that if a species is not on the list that species is not in jeopardy. This, of course, is not how the list should be interpreted. Many species that are not on the list should be, but are not, simply because we don't know enough about them. To correct this tactical error, it has been suggested that rather than constructing red lists we should construct "green lists." Green lists would include species that we know are secure. To be on the green list a species should meet the criterion of "known not to be declining in numbers now, and unlikely to decline in the next decade" (Diamond 1988). With a green list, it is argued, the burden of proof is shifted to those who wish to maintain that all is well with a species.

Those proposing green lists have been concerned with birds, not with bats. Certainly, much more is known about the status of birds than of bats. However, it is estimated that fewer than 1/3 of the world's bird species would qualify for inclusion on a green list. This being the case with birds, I also suspect that fewer than 1/3 of the world's bats likewise would qualify for such a list.

SOME THINGS THAT WE DO KNOW

With our ignorance as a perspective, I wish to consider some of what we do know about the status of bats, particularly cave bats. This requires going back to the red list. Of the 39 bat species in North America, north of Mexico, 18 rely substantially on caves for roosting sites. Some of the remaining 21 species also are occasionally found in caves, but caves evidently are not absolutely essential to them. Of the 18 species for which caves are essential, 13 species utilize caves year-round; both for reproduction and as winter roosts. The remaining 5 species rely on caves as hibernating sites, but roost elsewhere during reproduction. Four of the 5 North American species on the red list require caves year round (Table 1), and one species (the Indiana bat) requires caves for hibernation, but roosts elsewhere during the summer. So all North American bats listed as threatened are cave-dwelling; there appears to be a correlation with cave-dwelling and species jeopardy. However, to hearken briefly back to our ignorance, it is easier (not easy, just easier) to assess the status of cave-dwelling bats than the status of bats that are more dispersed in their roosting habits, and thus more difficult to find and monitor. The bias toward cave-dwelling bats being on the threatened list may in part be a result of relative ease of censusing.

Table 1. Officially endangered North American bats* and their use of cave roosts.

Species	Cave Roost Requirements
Indiana Bat *Myotis sodalis*	Winter Hibernacula
Gray Rat *Myotis grisecens*	Year-Round
Big-Eared Bat" *Plecotus townsendii*	Year-Round
Sanborn's Long-Nosed Bat *Leptonycteris sanborni*	Year-Round
Mexican Long-Nosed Bat *Leptonycteris nivalis*	Year-Round

* These species are listed on both the IUCN Red List and the U.S. Fish and Wildlife Service Endangered Species List.

** Two subspecies of big-eared bats are listed. These are the Ozark big-eared bat (*P. t. ingens*) and the Virginia big-eared bat (*P. t. virginianus*).

LIFE HISTORY TRAITS PREDISPOSING BATS TO EXTINCTION

Unlike most small mammals, bats have extremely long life spans. Even the smallest bat typically has a life expectancy on the order of 10 years, and individuals are known to live much longer than this. Wild little brown bats, for example, are known to survive as long as 30 years (Keen and Hitchcock 1980). In addition to long life expectancies, bats have very low rates of reproduction. Many female bats do not reproduce until their second year and, after reaching maturity, females usually produce only a single pup each year. Consequently, bats have far lower potential rates of population growth than are typical of most small mammals. Although bats are often perceived of as similar to rats or mice, the reproductive rates of bats are, in contrast, more similar to those of antelopes or primates. If a bat population is decreased in size, it can recover only slowly.

Bats have other characteristics which contribute to their vulnerability. Among the most significant is their habit of roosting together in large aggregations. The fact that large numbers of individuals often are concentrated into only a few specific roost sites results in high potential for disturbance. Because of their aggregative roosting habits, species that are very common actually can be vulnerable because they are in only a limited number of roosts. Mexican freetailed bats *(Tadarida brasiliensis mexicana*) are an excellent example. Single cave roosts of these bats can contain tens of millions of individuals and the loss of even one such roost would mean the loss of a significant portion of the entire species population.

DISTURBANCE OF ROOSTS BY HUMANS

Aggregations of bats are vulnerable to a variety of human-caused disturbances. At least 3 North American endangered species (Indiana, gray, and Sanborn's long-nosed bats) are known to have abandoned traditional roost sites because of commercial cave development (Humphrey 1978; Tuttle 1979; Wilson 1985a). An important hibernaculurn for endangered big-eared bats has been threatened by quarrying (Hall and Harvey 1976), and I personally have observed numerous examples of vandalism such as burning old tires, or shooting guns inside bat cave roosts. Although intentional disturbance of roosts is well documented, unintentional disturbance often poses an even greater threat. In the temperate zone, aggregations of bats which cavers typically encounter are either hibernating groups that occur in late fall, winter, and early spring, or maternity colonies that occur in late spring or summer. There is no question that disturbances as seemingly trivial as merely entering a roost area, or shining a light on hibernating bats or on a maternity group of females and their pups, can result in decreased survival, perhaps outright death, and possible abandonment of the roost site. Although there is some controversy about the significance of this apparently "innocent" disturbance, my own experience and reading of the literature lead me to the opinion that it can be extremely significant. However, there is no question that the impact of such disturbances are somewhat species-specific, and that the timing of the disturbance is very important.

The results of "innocent" disturbance of a maternity colony can include the following. (1) It can cause individuals to abandon roost sites, particularly early in the reproductive season when females are pregnant. This may result in females moving to other, perhaps less ideal, roosts where their success at reproducing is reduced. (2) Disturbance raises the general level of activity within roosts. This may result in greater expenditure of energy and less efficient transfer of energy to nursing young. This, in turn, may cause slower growth of young and increase the foraging demands on females, thus increasing the time females are outside of the roost and vulnerable to predation. (3) Disturbance can cause outright death of young that lose their roost-hold and fall to the cave floor. (4) Maternity aggregations often result in thermoregulatory benefits. Clustering bats gain thermal benefits from being surrounded by other warm bodies. However, individuals also may receive thermal benefit because the accumulated body heat of all individuals present serves to raise temperatures within the roost area. Therefore, if the size of a colony decreases, the accumulated thermal advantages to the individuals in that colony may likewise decrease, and it may become energetically less advantageous, or perhaps even energetically impossible for females to raise pups in that roost. Thus, there may be a "threshold," where after a population reaches a certain lower size, roost temperatures cannot be raised sufficiently for rearing young and that roost must be abandoned as a maternity site.

Problems caused by disturbing hibernating bats also relate to their energy requirements. During winter, temperate zone bats go long periods without eating, and allow their body temperatures to drop, often to near freezing. The energy reserves that bats accumulate prior to hibernation are often close to what is needed to survive the winter. Disturbance during hibernation may cause bats to arouse prematurely, elevating their body temperatures and utilizing stored energy reserves which should not be spared. The bats may go back into torpor after the disturbance, but then they may not have sufficient energy to survive the rest of winter. This may not be apparent to the person causing the disturbance.

Roost site disturbance also can seriously impact bats which do not form large aggregations. This is undoubtedly so for many tropical bats which roost in mature, hollow trees, which are being cut as more tropical forest goes into cultivation. To my knowledge, we don't know the trajectories of populations of any of these tree-roosting bats. As an example closer to home, it seems probable that the decline of the Indiana bat may be attributed in part to the loss of roost sites other than caves. Indiana bats hibernate in caves and there is no question that disturbance of hibernacula has contributed to their decline. However, in the midwestern United States, several large hibernacula of Indiana bats are protected from disturbance, yet these cave populations continue to decline (Clawson 1987). We can only speculate on the reasons for this continued decline, and this again points to our ignorance. However, while Indiana bats hibernate in caves, in summer they roost and give birth in tree hollows and under the loose bark of trees. The loss of tree roosts may very well be a serious factor in the continuing decline of the Indiana bat in the Midwest. That the decline of the Indiana bat may be due in part to factors outside of their hibernacula in no way implies that disturbances at hibernacula are unimportant. Rather, it emphasizes the importance of protecting hibernacula so as not to add additional stresses to these populations.

HABITAT DEGRADATION OUTSIDE OF ROOSTS

Man also has impacted negatively on bat populations by causing habitat alteration and degradation outside of their roost sites. For example, two species of North American bats on the red list are endangered, in large part, because man's activities have decreased their food resources. Both species of long-nosed bats inhabit desert regions of the Southwestern U.S. and Mexico, and both feed on the nectar and pollen of desert flowers (Wilson 1985a, 1985b; Anonymous 1988). Wild agave is a major food source of both species. Wild agaves have been severely reduced because they interfere with cattle grazing and because they are harvested by moonshiners for making tequila. Although long-nosed bat populations also have been affected by interference with their cave roosts (Wilson 1985a, Anonymous 1988), the reduction in agaves is clearly important in their decline. Long-nosed bats also are major pollinators of both organ pipe and giant Saguaro cacti. The well-known decline of these cacti also is evidently directly attributable to the decline of long-nosed bats (Wilson 1985a, 1985b; Anonymous 1988).

THE ROLE OF PESTICIDES

Pesticides used to control insect populations have negatively impacted populations of many bats (Clark 1981). Two effects seem likely; (1) direct poisoning of bats, and (2) reduction in the resource base of bats which eat insects. At present, we know little regarding the effects caused by pesticides reducing the insect prey of bats. However, direct poisoning by DDT (now banned for use in the U.S.) and other organochlorine pesticides has been widely implicated in the decline of many bats (reviewed in Clark 1981). While pesticide poisoning clearly has caused the decline of local populations of many bats, there has been a tendency to over-emphasize the importance of pesticide poisoning as one of the major factors in the decline of bats (Clark 1981; McCracken 1986). In fact, I question whether the general decline of any bat species can be attributed solely or even largely to the toxic effects of pesticides. This is not to exonerate pesticides, but rather to point more strongly at what are the major causes of bat population declines: i.e. roost site interference and the reduction of resources. I suspect that overemphasis of the importance of pesticide poisoning serves to draw attention away from these other causes.

How do I justify these statements? First, the belief that bats are unusually sensitive to pesticides dates from an early paper which purported to document their extreme susceptibility to DDT poisoning (Luckens and Davis 1964). It is now established that the susceptibility of bats to DDT is in general no greater than that of other similar sized animals (Clark 1981). Second, there have been many observed, dramatic declines of bat populations that have been attributed to DDT poisoning, without strong data to support these attributions. The most spectacular of these occurred in Eagle Creek Cave, Arizona, where the population of Mexican free-tailed bats declined from an estimated 30 million to an estimated 30 thousand individuals. While other toxins, such as methyl parathion (Clark 1986), may have contributed to this decline, and human disturbance also seems a likely culprit, there is no evidence that DDT poisoning was a major cause of the loss of this population (Clark 1981; McCracken 1986). Again, this is not to say that DDT or other toxins have not directly killed bats. It is well documented, for example, that young Mexican free-tailed bats from Carlsbad Caverns have had potentially lethal pesticide concentrations. However, this is evidently a local problem that has not been reported in other colonies of this species (Geluso et al. 1981). Finally, a natural "experiment" on DDT poisoning has been done for us. In the early 1960s, Cave Springs Cave in Alabama housed a major maternity colony of gray bats. This cave was heavily disturbed by humans and by the early 1970s all its gray bats were gone. However, Cave Springs Cave was then protected by fencing and its gray bat population began recovering to the point that it now houses an estimated 50,000 individuals. Cave Springs Cave is near a former DDT processing plant which also was a major toxic waste dumping site. At present, the bats and bat guano within this cave are substantially polluted with a variety of toxic chemicals including DDE (derived from DDT) an PCBs. Although, this bat colony experiences occasional dieoffs resulting from these toxins, the colony has nonetheless continued to recover in the face of these pollutants; this recovery dating from when the cave was protected (Tuttle 1986).

RED CAVES/GREEN CAVES

From what we know about human-caused impacts on bat populations, there is little question that roost-site disturbance, vandalism, and habitat destruction have had severe effects. This is particularly so for cave-dwelling bats. My opinion that these impacts are likely to have had greater negative effects than pesticide poisoning is shared by other researchers (Clark 1981; Tuttle 1985). People who visit caves, both professionally or for sport, must be acutely aware of the potential damage they can do to resident bats. To minimize such damage, we should recognize that there are caves ("Red Caves") which should not be visited by humans at any time, or only visited during certain times of the year, and other caves ("Green Caves") which are not important to bats or other threatened species and can be open to visitation. Bats select caves as hibernacula or as maternity sites because they fulfill very specific requirements. Fulfilling these requirements depends on cave structure, air circulation patterns, temperature profiles, and the cave's location relative to foraging sites (Tuttle and Stevenson 1978; Tuttle 1979). Because the requirements of bats are highly specific, those caves which do fulfill them will be relatively rare and may be absolutely essential to the bats. There may simply be no acceptable, alternative roost sites available. These caves must be placed on our red fist. Conversely, most caves will not satisfy these requirements and will not be important as bat roosts. These can be placed on a green list. It seems likely that the vast majority of caves would go on the green list. For example, less than 5% of caves surveyed in the southeastern U.S. were found to be physically suitable as gray bat maternity or hibernating roost sites (Tuttle 1979).

A major problem, of course, will be deciding whether a cave belongs on the green versus the red list. One obvious criterion is that major hibernacula and maternity roosts of threatened or declining bats should be red-listed, at least during the seasons when bats are present. Conversely, caves which are not occupied by bats and for which there is no evidence of prior occupancy should be green-listed. But, obviously, judgments will have to be made, often with only limited information. For example, it can be argued that historically important roosting sites that are now abandoned should be red-listed, at least temporarily, in the hope that they will be re-occupied. It also can be argued that caves with only small colonies should be red-listed, possibly for gene pool conservation, or that caves important to transients during seasonal movements should be red-listed during the relevant seasons. On the other hand, there may be no harm in green-listing some cave roosts of abundant, widely dispersed species (e.g., those of eastern pipistrelles), particularly if those caves have inherent interest to cavers.

Although listing caves for no or restricted access because of their use by roosting bats is likely to be controversial, these listings are necessary to preserve bat populations. Individuals who explore caves for sport or scientific study have a high probability of encountering roosting bats. The NSS as the largest single organization of cavers has the opportunity to provide education regarding potential impacts on bat populations to large numbers of people who are likely to encounter bats. In addition, cavers often have knowledge of bat roosting sites, and this knowledge is essential to informed and responsible listing of caves on red or green lists. Opportunities are abundant for cavers to cooperate with state, national, and private conservation agencies in identifying and preserving sensitive cave habitat. Several NSS grottos have taken the initiative themselves to construct, or are in the process of constructing, red and green lists of caves. These people should be supported in their efforts. Efforts to construct these lists should be expanded.

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